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*The European Corn Borer
in Maine —*

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SUMMARY

The European corn borer, first found in this country near Boston in 1917, was at once recognized as a threat to the corn growing industry of the United States. In spite of all efforts at containment, the borer spread and now occupies a wide area, covering much of the corn-growing regions of the nation. The first infestation in Maine was reported in 1922 from York County and now all the corn growing counties are inhabited by the European corn borer.

Sweet corn, field corn, and ensilage corn are infested by the borer. Losses are considerable in some fields each year but it is seldom that late corn is seriously injured by the borers in the single generation area. On the other hand, the two generation or bivoltine strain of the European corn borer sometimes extensively injures late planted corn in a limited area in southwestern Maine.

A thorough understanding of the life history and habits of the European corn borer is essential to its effective control. The life stages of the European corn borer are borer or larval, the pupal, the moth, and the egg.

The larvae are tiny when first hatched but attain a length of from $\frac{3}{4}$ to 1 inch when fully mature. The univoltine strain becomes fully mature at about the time when sweet corn is harvested. The borers hibernate mostly in corn stalks where they change to pupae beginning in June. Moths emerge in central Maine in late June and July, and the eggs are mostly laid on corn leaves from mid-July to August. Egg hatching follows and most of the borers are hatched by early August. The young borers feed upon the corn leaves around the central whorl and attempt to reach the developing tassel, a favorable environment for the young borers, which grow rapidly and feed extensively on the corn plants. Feeding on the corn plant is characterized by broken tassels, burrowed stalks, broken plants and damaged corn ears. Such damage results in considerable monetary loss to corn growers, as well as those who market or process sweet corn.

As the season advances and the borers reach maturity they retreat toward the base of the corn plant and can be found in their burrows near the base of the corn plant when winter arrives. Careful plowing covers the corn stalks containing the borers. Those coming to the soil surface and finding no shelter perish.

The time when the moths emerge along with cumulative temperature is used as a basis for forecasting when the borers will hatch. With this knowledge is coordinated field examination for borer presence and a consideration of corn growth stages susceptible to attack. Corn growers with this information available are able to examine their corn and judge for themselves whether or not insecticidal control is necessary. Corn in early tassel to mid-silk stage at the time when borers are

hatching is quite susceptible to borer injury. In general corn borers hatch when corn is in the prewhorl stage, at which time the corn plants are only 12 to 14 inches high and the tassel cannot yet be seen, are not likely to heavily infest corn.

The corn earworm and fall armyworm often attack corn ears and are sometimes confused with the European corn borer. When fully grown they are much larger than the mature European corn borer. Both the corn earworm and the fall armyworm carry stripes lengthwise of their bodies and the moths of both fly into Maine from outside, neither being able to winter here.

Natural enemies of the European corn borer consist of a considerable number of parasites and predators. Most of those affecting the borers here are native to Maine. Some exotic parasites have been introduced and at least one species is still extant in Maine.

Two generations of European corn borers are present in southwestern Maine. However, there are few borers of a second generation to be found in other Maine areas. It is possible that only the two-generation strain of borers is present in Maine and that what we ordinarily consider the single generation, or univoltine strain is composed of individuals of the two-generation strain which fail to develop a second generation in central Maine because of the shortness of the season.

ACKNOWLEDGMENT

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THE EUROPEAN CORN BORER IN MAINE

Its Biology and Life History

JOHN H. HAWKINS AND JOSEPH J. DEVITT¹

INTRODUCTION

The European corn borer is an immigrant. The first known infestation in the United States occurred near Boston, Massachusetts, in 1917.

It was at once recognized as a serious threat to the corn industry and organized attempts were made immediately to prevent the pest's spread. But in spite of those efforts the borer rapidly invaded other areas. Now it is found over most of the corn growing sections of the country, as far west as Montana and as far south as Alabama. The borer is also well established in Canada, particularly in Ontario, where considerable loss occurs each year.

The European corn borer was reported in southeastern New Hampshire, just across from the Maine border, in 1922 by Caffrey and Worthley (3).² By 1927 it was established in the coastal areas of southwestern Maine from where it spread to all the principal corn growing areas of the State.

Corn losses caused by the borer fluctuate from year to year, depending upon control measures and infestation. Years of relatively light infestation may often be followed by years of more than normal injury. Both sweet corn and field corn are damaged, the latter sometimes suffering severely in Maine since it is planted early to allow time for maturing before frost.

Invasion of the corn ears by the European corn borer may make the market garden or canning ears unsalable; even in areas of light infestation canning costs are increased by the necessity of close

inspection of the ears to exclude all borers from the cans. Reduced yields result from lodging of plants. Uneven maturing is caused by broken or weakened ear shanks that have been injured by the borers.

Indications are that the destructive insect can never be completely eradicated; therefore, it is important that all promising control methods be used to keep borer infestation at a minimum.

A better understanding of the appearance, life history, and bionomics of the European corn borer is essential to improved control. These have been studied carefully and are discussed in this publication.

The discussion primarily concerns the single generation corn borers which predominate in most of Maine's corn producing areas, particularly in those in which the frost-free period averages about 110 days. Two-generation borers predominate in one area—a narrow coastal zone of longer summers in southwestern Maine—and are discussed in the last section of this publication.

DESCRIPTION OF EUROPEAN CORN BORER

Pupae of the European corn borer are small, brownish, and somewhat spindle-shaped (Fig. 1). Pointed at one end and blunt at the other, they are about five-eighths inch long and one-eighth inch in diameter. There is considerable range in size and color between individual pupae. The pupae are enclosed inside their host plant in cells sparsely lined with silk (Fig. 1). The last larval skin with its head capsule is usually attached to or is near to the sharp end of the pupal abdomen.

Adult European corn borers are small, brownish or yellowish moths which vary in color from dark brown to light tan

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² Numbers in parentheses refer to Literature Cited, page 26.

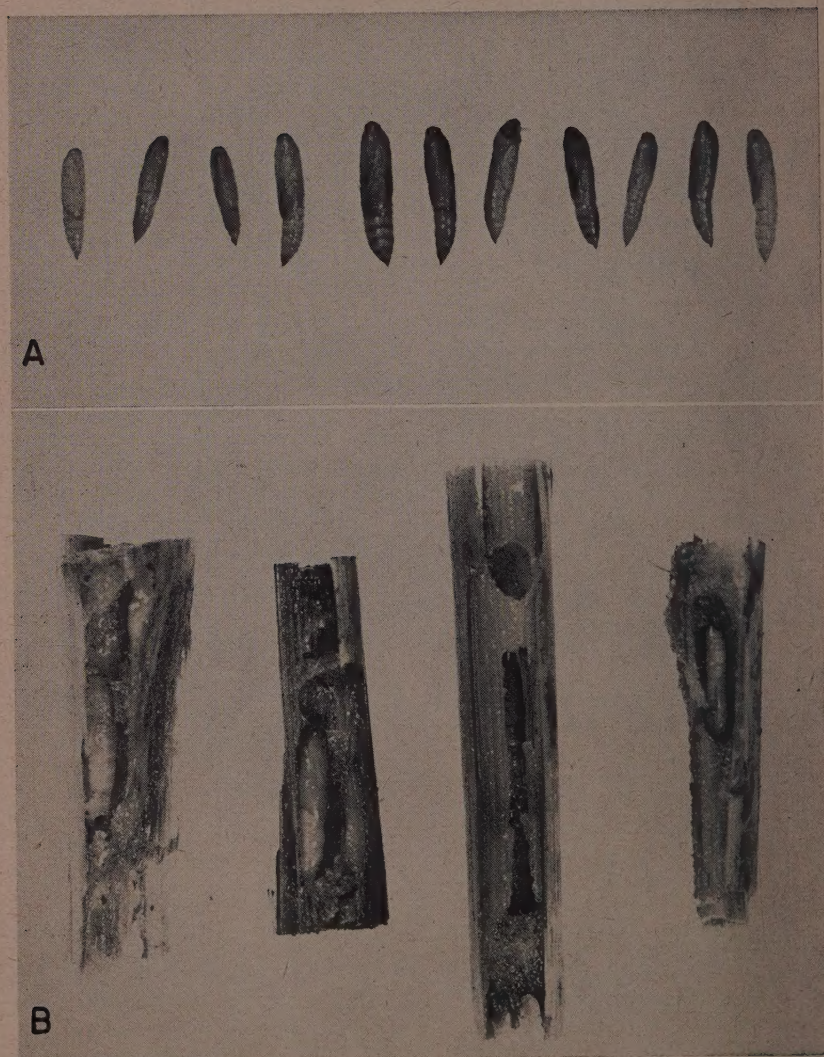


FIGURE 1. Pupae of the European corn borer. (A). Removed from pupal cells in corn stalks. (B). Corn stalk cut away to show pupae inside cells.

and have contrasting, dark, and zigzag transverse lines on the wings (Fig. 2). Males are usually darker than females. The body length of the moths varies from about $\frac{1}{2}$ to $\frac{7}{8}$ inch. The wings, when fully extended, measure about $1\frac{1}{4}$

inches from tip to tip.

Eggs of the European corn borer are minute in size (Fig. 3). They are laid overlapping in irregular groups of from a few to 50 or more eggs. The egg cluster appears as a tiny white patch, which



FIGURE 2. European corn borer moths (twice actual size). Male above, female below.

can be detected on the under sides of the leaves of the corn plant only by close examination. At first the eggs are almost transparent, and resemble fish scales (Fig. 3), but as they become older the black heads of the developing larvae can be seen inside in the so-called blackhead stage (Fig. 3).

The larva of the European corn borer is less than $1/16$ inch long when first hatched (Fig. 4). It is quite dark in color and long hairs are thinly set on the upper surface and sides of the body. The larvae, as they become older, are lighter in color, and brown spots or tubercles arranged in longitudinal rows can readily



FIGURE 4. European corn borer larvae. (A). Dorsal view of large fully-fed larva ready for hibernation. (B). Lateral view of the same. (C). Ventral view showing underside of body and legs.

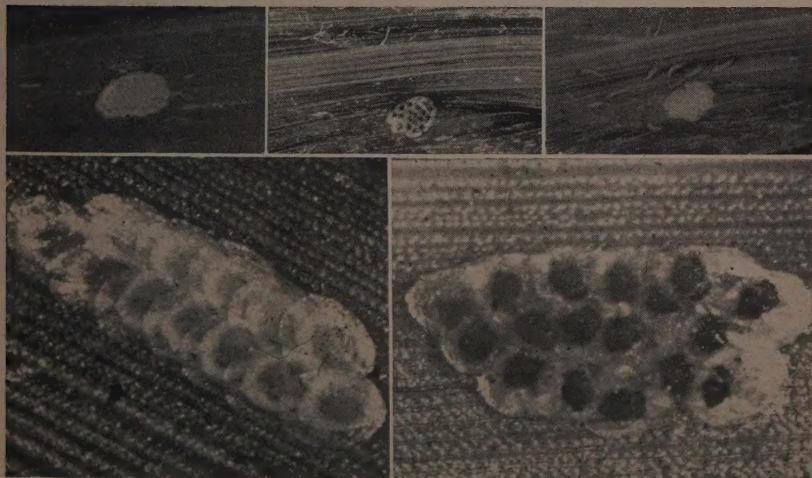


FIGURE 3. Eggs of the European corn borer. Top row (twice actual size): Left, eggs freshly laid. Center, eggs in "blackhead" stage. Right, larvae hatching and dispersing from egg mass. Bottom row (greatly enlarged to show details of shape and how eggs overlap): Left, egg freshly laid. Right, "blackhead" stage.

be seen on the body. Heads of the older larvae vary from dark to light brown. As the larvae reach maturity, they appear as smooth, cream colored, purplish, or tan colored caterpillars (Fig. 4). When fully grown some of the larvae are about one inch long with a diameter of $\frac{1}{8}$ inch or more, although many are smaller.

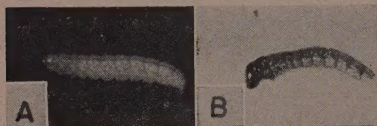


FIGURE 4A. European corn borer larvae. Right, young larva magnified about 12 times. Head is much larger than body in early instars. Left, mature larva removed from hibernating cell. This larva is slightly smaller than normal fully fed larva.

LIFE CYCLE

The four stages in the life history of the European corn borer are: (1) the borer or larval stage, (2) the pupal or resting stage, (3) the adult moth, or egg laying stage, and (4) the egg stage.

The single generation borers or larvae hatch chiefly in July. By fall of the first year they have reached their maximum larval growth and hibernate in corn stalks or other large stemmed plants. Early in June of the next year the borers or larvae begin to pupate. The largest number pupate during this month. The nocturnal moths begin to emerge in large numbers in late June and most of the moths have emerged by the first of August. Most of the eggs of the European corn borer are laid during the month of July although records show that eggs are laid as early as June 13 and as late as August 28. Hatching of the eggs occurs from June 24 to September 5, with the greater portion of hatching during the last half of July. The borers grow rapidly during August and September and work toward the bottom of the host plant for winter hibernation.

LIFE HISTORY OF THE UNIVOLTINE STRAIN IN MAINE Larval Stage and Plant Injury

The larvae hatch in July and August and congregate on the underside of the corn leaves (the point of hatching) where they feed upon the external portions of the leaves. They soon disperse under normal conditions, however. These feeding areas are characterized by light colored, sawdust-like frass, left at the edges of the feeding areas, and appear as small, translucent spots in the leaf. The translucence is caused by the larvae having eaten away the green matter from the fleshy part (Fig. 5).



FIGURE 5. Characteristic "pin hole" damage to leaves of corn plant, caused by feeding of newly hatched larvae.

The larvae disperse by crawling, going into the leaf whorl and unfolding tassel, or into the leaf sheath below the auricle at the base of the leaf. A secondary method of dispersion is for the larvae to suspend themselves from the edge of the leaves by spinning a silky thread. Wind currents then carry them to other leaves or plants.

European corn borer larvae may pass through as many as seven instars, as

shown by laboratory experiments at Newport, Maine, in 1947. This is more than the commonly reported number (4, 9). Newly hatched larvae usually outgrow their skins and moult for the first time three or four days after hatching. The next two or three moults occur at 4- or 5-day intervals. As the larvae grow, the time between moults increases.

Just before moulting, the developing new head capsule appears as a thin, brownish, collar-like band below the head capsule. When ready to moult the larva spins a thin silk web about itself. Then the skin splits, the head capsule is cast off, and the larva wriggles out of the old skin. Frequently they eat the cast-off skin, or a portion of it. The new head capsule, originally light in color, gradually darkens, becoming dark, shiny brown before the next moult.

Young larvae often enter and feed on the tassel buds. The tassel buds and tassel bracts frequently are webbed together

early in the season, forming an enclosed feeding area and a temporary shelter for moulting. After leaving the tassel buds the larvae bore into the tassel stalk at its juncture with the top leaf on the plant. The rapidly growing larvae feed extensively inside the small stalks and so weaken them that the tassel breaks over. The fallen tassels, which usually remain hanging from the plant, plainly advertise the infestation (Fig. 6). However, by the time the broken tassels are observed it is too late for efficient insecticidal treatment.

After feeding in the tassel, a few larvae burrow into the midrib at the base of the leaf, feeding there for several days. More commonly the larvae tunnel into the stalk just above a node and burrow upward to the next node (Fig. 7). Here they usually emerge and move down the stalk to a lower internode.

Injury to corn ears is sometimes extensive. When partly grown, borers reach



FIGURE 6. Corn plant tassels broken over after tassel stems had been weakened by borer tunneling.



FIGURE 7. Corn borer larva tunneling in internode of cornstalk. Borer tunneling upward from entrance at lower node of cornstalk.

the junction of the ear with the main stalk. They may enter the ear shank or bore through the husk to the ear (Fig. 8). Destruction here takes several forms. They eat on the kernels and on the cob, causing disfigured ears (Fig. 9). Sometimes the injury is internal and may include a tunnel in the pith of the cob (Fig. 10).

Injury to the corn plants may be so extensive when a large number of borers are present that many of the plants break over (Fig. 11). Even though dwarfing of the ears and reduction in quality may be great, it is sometimes less important than corn plants falling to the ground or dropping off of ears because of the feeding of borers in the ear shanks.

As the season progresses and the temperature falls, the borers gradually make their way downward, and before the arrival of winter are located within a few inches of the soil surface.

Careful plowing during the fall months covers the borer-infested corn plants with a little to several inches of soil. Thus covered, some live until spring. Other winter quarters are sought by some which make their way to the surface and enter corn stalks or stems of other plants for shelter. When they find no such material in cleanly plowed fields the borers perish on the barren surface of the soil.

Mortality in the larval stage is high. Often more than 80 per cent of the European corn borer eggs hatch, but the average at harvest time is about 14 per cent of those originally hatching. (Table 1).



FIGURE 8. European corn borer larvae tunneling ear and shank (after Hervey, 1932).



FIGURE 9. Ears of sweet corn discarded at canning plant because of corn borer injury.

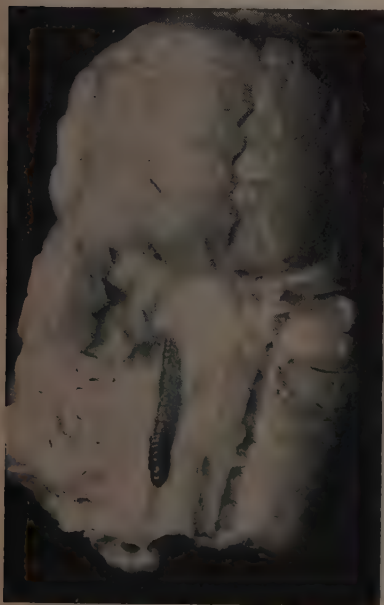


FIGURE 10. Borer inside of cob of corn. Part of ear cut away to show tunnel which sometimes runs full length of pith of cob.



FIGURE 11. Breakage of corn plants through weakening of stems by tunneling of European corn borer larvae. Loss in this field estimated at 50 per cent.

TABLE 1

Mortality in the Larval Stage

Year	Number of Eggs Hatched	Number of Larvae Surviving at Harvest Time	Per Cent of Larvae Surviving
1949	3,752	856	22.8
1950	8,318	1,194	14.4
1951	14,819	1,861	12.6
Average	8,963	1,303	14.5

Overwintering Larvae and Pupation

The overwintered European corn borer larvae found during the spring in central Maine are mostly of the single generation or univoltine strain. The hibernating larvae are to be found usually inside corn stalks of the previous season's crops.³ The exit hole from the cavity in the corn stalk is closed by a light web of silk. Inside the winter burrow the larva usually surrounds itself with a silken web. In corn fields where the plants have been left standing, the borers are found mostly near the soil surface in the bases of the corn plants. Where the fields have been plowed, the borers can be found in the stalks or pieces of stalk both above and below the soil surface. When the fields are harrowed the borers are often broken out of the original burrows and take refuge in such corn stalks or pieces as are to be found on the surface. Some of the borers in the old, plowed-under stalks are brought to the surface during spring soil preparations. Many of these are able to complete their life cycle, since they find shelter in other stalks and plants.

³ A long list of host plants of the European corn borer in New England has been recorded (7). However, infestation has been confined almost exclusively to the corn plant in Maine. Occasionally a feeding borer has been found in bean pods, raspberry vines, potato plants, hollyhocks, and barnyard grass. The total number of European corn borers found feeding in these auxiliary hosts in the State is very small. In the spring, however, it is common to observe the overwintered larvae sheltered in the stems of dead weeds such as red root, pigweed and mustard.

General observations indicate that cultivation, such as plowing or harrowing, kill or injure some borers. A field at Monmouth, Maine, was observed during several harrowings in the spring of 1950. The borer population decreased with each harrowing. There was also evidence that birds and a small elaterid beetle, *Cryptohypnus abbreviatus*, Say, preyed on borer larvae exposed by the harrowing.

Pupae of the European Corn Borer

Data on European corn borer pupation are the results of several years' study in Maine. The earliest date recorded for European corn borer pupation in central Maine was on May 22 (Table 2). However, pupae ordinarily are not observed until well into June.

TABLE 2

Date of Field Pupation of European Corn Borer
(Date when first pupae were observed)

Year	Month	Day
1947	June	13
1948	June	14
1949	June	4
1950	May	22
1951	June	2

Pupation was approximately 95 per cent completed on June 14, 1952 in York County where the two-generation strain of the European corn borer predominates.

Pupation studies of 100 borers confined in cages in each spring of 1947, 1948, and 1950 are the basis of Table 3. Pupation of the single or univoltine strain continues until about August 1 in central Maine, although the peak of pupation is reached from July 10 to July 17 on an average.

Single generation borers observed in rearing cages in 1950 spent from 9 to 22 days and the average duration of the pupal stage was about 15 days (Table 4).

Pupal mortality ranged from 17.0 per cent to 36.8 per cent in 1950. Many factors affect the number of pupae sur-

TABLE 3

Date and Number of Larvae Pupating in Cages
Summary of 1947, 1948, 1950

Date	Number in Pupal Stage	Date	Number in Pupal Stage	Date	Number in Pupal Stage
June		July		July	
26	1	7	61	20	42
27	2	8	68	21	35
28	4	9	74	22	30
29	6	10	81	23	22
30	9	11	84	24	16
		12	84	25	14
July		13	88	26	9
1	16	14	88	27	8
2	26	15	85	28	7
3	36	16	86	29	5
4	39	17	81	30	5
5	50	18	73	31	5
6	56	19	64		

TABLE 4

Duration of Pupal Stage of the
European Corn Borer, 1950

Maximum number of days	22
Minimum number of days	9
Average	14.9

viving when a given number of larvae are reared in cages. Collecting and rearing operations affect the larvae and secondarily, pupal survival. In rearing cages, both larvae and pupae fall prey to invading ants. However, larvae and pupae reared in cages escape injury caused by birds which frequently prey on them in their natural environment. The number to be expected from a given number of larvae or pupae is given in Table 5.

Emergence and Life Span of the Moth

The emergence of the adult European corn borer moth is related to temperature during the spring developmental period.

Studies from 1945 through 1951 indicate that high temperatures previous to emergence hasten that event (5). Successive days and nights of relatively high temperature during the emergence period causes the emergence of large numbers of the moths within a short time; lower temperature retards emergence, thereby lengthening the pupal stage and prolonging the period over which moth emergence occurs.

Repeated studies in Maine on the effect of rainfall and humidity upon the life of the European corn borer indicate that these weather factors are less important than temperature in influencing moth emergence.

Emergence time range, that is, the time between the emergence of the first moth and that of the last, varies from year to year. This variation was studied for 10,696 moths from 1947 to 1951 (Fig. 12 and Table 6). The earliest date of

TABLE 5

Number of European Corn Borers Completing Pupal Stage

Date study began	Number larvae	Number pupated	Number completing pupation	Percentage completing pupation	Percentage mortality
6/24/47	100	100	83	83.0	17.0
6/21/48	100	91	60	65.9	34.1
6/30/50	100	95	60	63.2	36.8

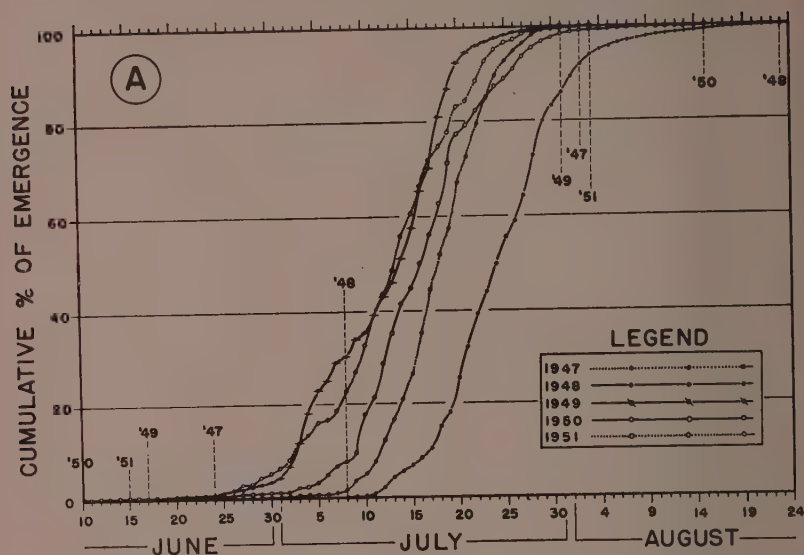


FIGURE 12. Cumulative percentage curves of European corn borer moth emergence for the years 1947-1951. Day of the month is on second line at bottom just above months June-August. Years '47 to '51 on graph indicate beginning and ending points for the curve lines. Lines are identified at right in chart.

emergence was June 10 and the latest, August 23.

Average date for emergence of the first moth for the five years was June 21 and for the last, August 8. This indicates that European corn borer moths of the single generation strain are on the wing in central Maine from about the end of the third week in June until August 1. Actually, European corn borer moths

have been taken at light traps at East Newport on August 23.

The relation of moth emergence, oviposition, and hatching has been considered as a basis for improving control through better timing of insecticidal application. Year to year variation in moth emergence is shown by the curves of cumulative emergence of European corn borer moths for 1947 through 1951

TABLE 6

Emergence of European Corn Borer Moths at Newport, Maine
1947-1951

Year	Number moths observed	Emergence began	Dates when specified percentages of moths had emerged						
			10 per cent	25 per cent	50 per cent	75 per cent	90 per cent	95 per cent	99 per cent
1947	868	June 24	July 12	July 15	July 18	July 21	July 24	July 26	July 29
1948	2633	July 8	July 17	July 20	July 24	July 28	Aug. 1	Aug. 4	Aug. 14
1949	2205	June 17	July 3	July 6	July 14	July 17	July 19	July 21	July 26
1950	2179	June 10	July 9	July 11	July 16	July 20	July 25	July 28	Aug. 2
1951	2811	June 15	July 3	July 9	July 13	July 18	July 22	July 24	July 30
Average dates			June 21	July 9	July 12	July 17	July 21	July 24	July 27 Aug. 2

(Fig. 15). The emergence curves follow a characteristic S pattern. The moths emerge slowly at first (see bottom of Figure 15), then begin to emerge rapidly. About the middle of July the curve flattens as moth emergence slows.

Variations between the earliest and latest dates of moth emergence are relatively less important for practical purposes than are the variations during the period of rapid emergence. The greatest difference between earliest and latest emergence dates for the 5-year period is 14 days, the 10 per cent emergence level being approximately 14 days later in 1948 than in 1951. A maximum difference of 10 days is recorded between the years of 1948 and 1951 for the 50 per cent level of moth emergence, and the same difference exists between these years from the 40 to 70 per cent level of moth emergence.

The greatest difference between years at the 90 per cent level is that of 13 days found between 1949 and 1948. The latest dates of emergence for the period from 1947 to 1951 occurred during the 1948

season. In general not more than two weeks variation can be expected from year to year for any given level of moth emergence.

The temperature as recorded for the year 1948 by the U. S. Weather Bureau at Winslow was 4.5 degrees below normal and the precipitation was 0.9 inch below normal. The moth emergence of 1949 was early, and the average annual temperature was 2.6 degrees above normal and precipitation was 4.4 inches below normal. If any generalization can be made from these data, it is that the higher temperature accelerated European corn borer moth emergence, a conclusion strengthened by the fact that increases in temperature tend to accelerate moth emergence.

Studies of cumulative emergence indicate that the greater percentage of the moths (10 to 80 per cent) emerge in a period of less than three weeks. This is significant since this rapid rise in corn borer moth emergence is followed by a similar rise in hatching of the larvae about two weeks later. Insecticide is

TABLE 7
Reproductive Capacity of European Corn Borer Moths in 1949

Emergence date of moths	Longevity (days)			No. of egg masses laid	Total No. of eggs laid	Oviposition dates	Hatching dates	Total No. of eggs hatched
	Female	Male (1)	Male (2)					
7/2	11	1	2	15	498	7/4-7/7	7/11-7/15	305
7/7	11		6	0	0	—	—	0
7/8	12	12	17	13	229	7/14	7/19-7/20	191
7/9	8	5	8	3	106	7/13-7/14	7/20-7/21	101
7/10	12	3	10	12	489	7/14-7/19	7/20-7/25	412
7/11	12	4	12	18	405	7/16-7/22	7/22-7/28	348
7/12	1	3	9	0	0	—	—	0
7/13	10	8	11	13	499	7/15-7/23	7/21-7/29	453
7/14	14	6	9	1	27	7/19	7/25	27
7/15	12	6	6	4	50	7/18-7/20	7/25	47
7/16	7	11	12	2	46	7/20-7/21	7/28	22
7/17	5	3	4	6	192	7/19-7/20	7/25-7/27	184
7/18	4	4	10	0	0	—	—	0
7/19	3	3	4	0	0	—	—	0
7/20	10	2	2	12	30	7/29	—	0
7/21	9	2	7	13	243	7/27-7/29	8/1-8/4	166
7/22	9	9	15	14	374	7/25-7/29	7/30-8/4	300
7/23	7	5	10	13	383	7/26-7/29	7/31-8/4	298
7/24	12	3	10	17	270	7/29-8/2	8/3-8/8	153
7/25	3	4	8	2	75	7/27	8/1	71
7/26	5	4	4	5	196	7/28-7/29	8/2-8/4	128
7/28	5	3	3	0	0	—	—	0
7/29	9	8	8	33	766	7/30-8/6	8/5	665
8/1*	7	9	—	15	542	8/2-8/6	8/8-8/14	321

* Second generation moths emerged from pupae brought to Newport from Potter Farm, Sabattus, Maine, July 25.

TABLE 8

European Corn Borer Oviposition at Newport, Maine
1947-1951

Year	Number Egg masses observed	Ovipo- sition began	Dates when specified percentages of egg masses had been laid							
			10 per cent	25 per cent	50 per cent	75 per cent	90 per cent	95 per cent	99 per cent	
1947	3,228	July 3	July 15	July 21	July 25	July 29	July 31	Aug. 2	Aug. 6	
1948	8,045	July 12	July 22	July 26	July 29	Aug. 2	Aug. 9	Aug. 14	Aug. 21	
1949	8,585	June 27	July 12	July 17	July 20	July 26	July 29	July 30	Aug. 4	
1950	9,517	June 13	July 14	July 19	July 25	Aug. 1	Aug. 6	Aug. 10	Aug. 17	
1951	12,190	June 17	July 12	July 17	July 22	July 27	Aug. 1	Aug. 4	Aug. 10	
Average dates			June 26	July 15	July 20	July 24	July 29	Aug. 3	Aug. 6	Aug. 12

most effective in this period of rapid hatching.

Preliminary studies of the length of life as well as the reproductive capacity of borer moths confined to cages (began in 1947) were continued during 1948 and 1949. One female and two male moths were confined in each of 24 oviposition cages. The cages were inspected

twice daily and humidity was maintained by wetting the cloth sides of the rearing cages. The data are shown in Table 7.

The longest life span recorded for a male European corn borer moth is 17 days (Table 7). One female moth lived 14 days. Average life of the male moths was 6.63 days and that of the females 8.25 days.

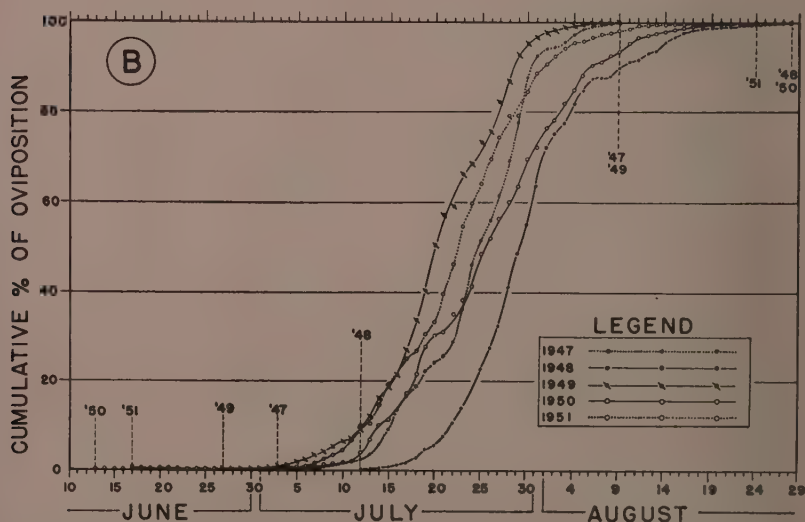


FIGURE 13. Cumulative percentage curves of the oviposition of European corn borer eggs at Newport, Maine, 1947-51. Day of the month is on the second line at bottom just above months June-August. Years '47 to '51 represent ends of curve lines. Curves are identified according to structural makeup in insert at right.

TABLE 9

Incubation Period of European Corn Borer Eggs—Field Data
Palmyra, Maine, 1949-1951¹

Length of incubation period (days)	1949		1950		1951		3-year Totals	
	Number egg Masses	Percentage of egg Masses	Number egg Masses	Percentage of egg Masses	Number egg Masses	Percentage of egg Masses	Total Number egg Masses	Percentage of Total
5	54	16.6	0	0	1	.1	55	3.6
6	141	43.4	14	3.0	85	11.4	240	15.6
7	69	21.2	68	14.6	174	23.3	311	20.2
8	52	16.0	131	28.1	280	37.5	463	30.1
9	9	2.8	157	33.7	132	17.7	298	19.4
10	0	0	81	17.4	57	7.7	138	9.0
11	0	0	10	2.2	15	2.0	25	1.6
12	0	0	5	1.0	2	.3	7	.5
Totals	325	100.0	466	100.0	746	100.0	1537	100.0

¹ Data collected from daily observation of egg masses from day of oviposition until day of hatching.

Egg Oviposition and Hatching

Eggs are laid in a period of slightly more than two months (Fig. 13 and Table 8). The earliest date recorded was June 17, 1951, and the latest August 28, 1949 and 1950. The average date of first oviposition from 1947 to 1951 was June 26 and for the last oviposition, August 19. The female moth normally begins to lay eggs within five days after emerging and the eggs are all laid within two weeks time.

The number of eggs laid per female moth varies greatly (Table 7). The number deposited nightly ranges from a few to 100 or more. The largest number recorded in central Maine for a single female was 33 masses, and the largest number of eggs produced by a single female was 766. The average number of egg masses per 100 females was 879 or nearly nine masses each. The average number of eggs produced by 100 moths was 22,583 or an average of approximately 226 eggs for each moth.

Hatching time of the eggs varied from 5 to 12 days (Table 9). Data were obtained during 1949, 1950, and 1951 from field plots of corn maintained in connection with survival studies in relation to corn growth stages. The modal number of days was six for 1949, nine for 1950, and eight for 1951. During the 3-year

study, 85 per cent of the eggs hatched in from six to nine days. Consecutive periods of relatively high temperature speeded incubation and uneven low temperatures retarded it.

The largest number of live larvae produced from eggs laid by a single female was 665 (Table 7). The average number per 100 moths was 17,467 or about 175 per female.

TABLE 10

Mortality in the Egg Stage

Year	Number of Eggs Observed	Number of Live Larvae Hatched	Per Cent of Hatch
1949	10,262	8,328	81
1950	12,938	10,927	84
1951	19,363	16,277	84

Mortality in the egg stage is something more than 15 per cent (Table 10). Mortality in the field is frequently high in this stage. Egg masses are found containing several dead, unhatched eggs.

The blackhead stage of the European corn borer eggs is important because blackheading of the eggs indicates that hatching is imminent (see description of blackhead eggs, page 7) and borers will soon start to infest the corn crop.

The variability of oviposition and

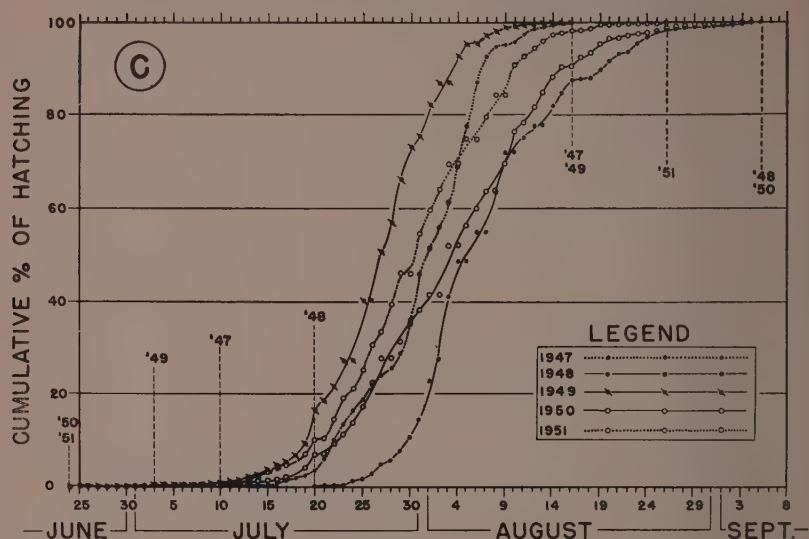


FIGURE 14. Cumulative percentage curves of the hatching of European corn borer eggs at Newport, Maine, 1947-1951. Day of the month is on the second line at bottom just above months June-August. Numbers '47 to '51 indicate points where curve lines begin and end. Curves are identified according to structural makeup in insert at right.

hatching from year to year is shown by the curves for cumulative oviposition and hatching of the European corn borer for 1947 to 1951 (Figures 13 and 14). Both figures have the characteristic S curve pattern found in the moth emergence curve (Fig. 12).

Variations between the earliest and latest dates of first and last oviposition (and hatching) are relatively less im-

portant for practical purposes than are those between 5 per cent and 95 per cent.

Between the 5 per cent and 90 per cent levels on the oviposition curves in Figure 13 there is a maximum difference in dates between the years of approximately 9 or 10 days. At the 95 per cent level there is a maximum difference of 15 days.

Hatching occurred 11 days earlier in

TABLE 11

Hatching of European Corn Borer Eggs at Newport, Maine
1947-1951

Year	Hatching began	Dates when specified percentages of egg masses had hatched						
		10 per cent	25 per cent	50 per cent	75 per cent	90 per cent	95 per cent	99 per cent
1947	July 10	July 22	July 28	Aug. 1	Aug. 5	Aug. 7	Aug. 9	Aug. 13
1948	July 20	July 30	Aug. 2	Aug. 5	Aug. 11	Aug. 19	Aug. 23	Aug. 30
1949	July 3	July 19	July 23	July 27	July 31	Aug. 4	Aug. 5	Aug. 9
1950	June 24	July 22	July 27	Aug. 3	Aug. 10	Aug. 15	Aug. 19	Aug. 27
1951	June 24	July 20	July 25	July 30	Aug. 6	Aug. 10	Aug. 12	Aug. 18
Average dates	July 4	July 23	July 27	Aug. 1	Aug. 6	Aug. 11	Aug. 14	Aug. 19

1949 than in 1948 at the 10 per cent level (see Fig. 14 and Table 11), earlier by 10 days at the 25 per cent level, by 9 days at the 50 per cent level, 11 days at the 75 per cent level, 15 days at the 90 per cent level, and 18 days at the 99 per cent level. Thus, there was an increasing variation between the same hatching levels for the 5-year period, as the latter part of the hatching season approached.

Figure 15 indicates that on the basis of a 5-year average (1947-1951), seven or eight days after a specified percentage level of moth emergence is reached the same percentage of oviposition will occur, and that seven or eight days later the same percentage level of egg hatching will be reached. Thus, a specified percentage level of egg hatching may be expected approximately two weeks after the same percentage of moth emergence has been observed. These data are helpful in insecticidal control of the European corn borer when they are used to help forecast the dates of maximum effectiveness of treatment.

Places selected by European corn borer moths for oviposition vary extensively. Egg masses have been found in all parts of fields, on both tall and short plants in the same field, on both main plants and tillers, and on all primary and secondary leaves. Studies to determine the relation between prevailing winds and location of egg masses on the plants have been inconclusive.

However, a few general observations may be made. Only once in the 6-year study has an egg mass been found other than upon the lower leaf surfaces of the corn plant. Almost always the egg masses are to be found between the top of the arch of the leaf and the leaf attachment to the stalk. They are more commonly found on the main plant than on the tillers. Also, the moths seem to select the tallest plants of a single variety of corn within a field. Old egg masses frequently are found on the lower or even the primary leaves of a small plant; fresh egg masses are more common on the largest leaves of more mature plants.

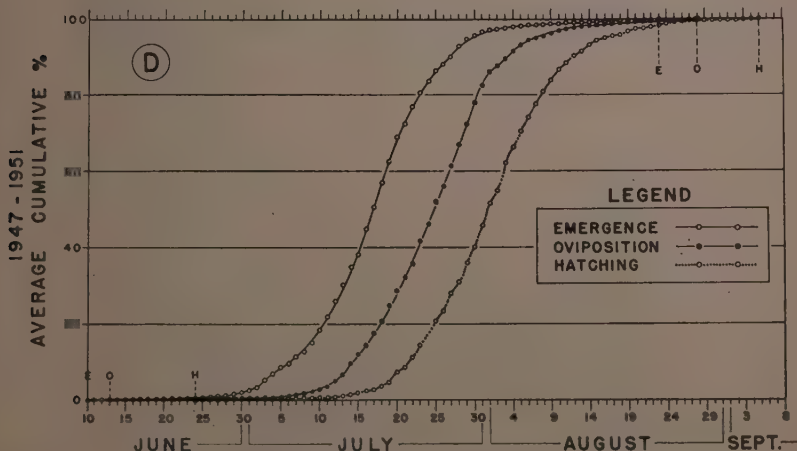


FIGURE 15. Five-year averages of the cumulative percentage curves of European corn borer emergence, oviposition, and egg hatching at Newport, Maine, 1947-1951. Curves are also referred to according to structural makeup in insert at right.

SURVIVAL IN RELATION TO CORN GROWTH STAGES

In central Maine (single generation area), early planted corn of given variety is more likely to be infested than is corn planted June 14 or later (6). However, planting corn in central Maine after June 14 is risky since the growing season is usually not more, and sometimes is less, than 110 days in length.

The fact that the taller corn plants in a field are more often selected by European corn borer moths is used to advantage by survey men looking for eggs. However, study of varietal infestation reveals that early maturing short varieties of sweet corn are sometimes more heavily infested than are later maturing tall varieties grown in the same field. The mere fact that a given corn variety is short is no assurance that it will escape borer infestation if it is planted at an early date. Egg laying usually is heaviest on those plants that are nearest to the tassel stages of development.

Corn growth stage is apparently important in infestation. Research over several years has covered variety trials, growth stage and infestation. Batchelder in 1949 (2) published information on the distribution of the corn borer larvae and described the various corn growth stages when insecticide applications should be made. Information from Batchelder's studies is the basis for Table 12, devised for use in Maine to describe corn growth in relation to control activities.

Figures 16 and 17 illustrate corn plant growth stages 2-10, inclusive. The borer population at different corn growth stages was the subject of investigation in field plot studies at Newport, Maine, in 1949, 1950, and 1951 (Table 13). Procedure followed was that of Patch and others reported in 1942 (8), modified for our conditions.

Table 13 summarizes the data collected during a three-year study. A total of 1097 plants were dissected. On these

TABLE 12

Corn Plant Growth Stages

-
1. *Prewhorl* (W-1)
-1 to 5 leaves
 2. *Early whorl* (W-2)
-6 to 7 leaves
 3. *Midwhorl* (W-3)
-8 to 9 leaves
 4. *Late whorl* (W-4)
-10 leaves
-tassel shows below edge of whorl cup
-primary leaves brown or lost
-ear shoot may appear
 5. *Early green tassel* (T-1)
-10 leaves
-tassel tip shows above edge of whorl cup
-ear shoots show
 6. *Midgreen tassel* (T-2)
-10 to 11 leaves
-tassel is a clump of adhering branches
 7. *Late green tassel* (T-3)
-11 leaves
-branches of tassel are unfurled away from stem
 8. *Early silk* (S-1)
-11 to 15 leaves
-tassel branches droop
-silk is yellowish green and sparse
-husk leaves lie forward from ear tip
 9. *Midsilk* (S-2)
-11 to 15 leaves
-tassel branches droop; maximum pollen shedding
-silk is dark colored and wilted at tips, and numerous
-husk leaves turned outward from ear tip
 10. *Late silk* (S-3)
-11 to 15 leaves
-tassel branches straight and at an angle to stem
-silk is dried and brown at tips only
-husk leaves lie back along ear
 11. *Roasting ear* (E-1)
-11 to 15 leaves
-silk is dried and brown most of length
-one ear full size and in "milk" stage
 12. *Mature* (E-2)
-11 to 15 leaves
-kernels in "dough" stage
-



FIGURE 16. Corn plant growth stages. (A) Midwhorl. (B) Late whorl. (C) Early green tassel. (D) Midgreen tassel.

plants 26,934 eggs had hatched. In the fall dissection, 3911 larvae were found.

The highest percentage of larval survival (24.7 per cent to 28.3 per cent) occurred when the eggs hatched during five growth stages of the corn plant—the early green, midgreen, and late green tassel; and the early and mid silk stages. During these stages the corn plant height varied from 21 to 79 inches. The maximum survival (28.3 per cent) occurred when the eggs hatched during the midgreen tassel growth stage of the plants. Plant height during this stage varied from 23-50 inches.

Survival was negligible (2.9 per cent)

when hatching occurred while the plants were less than 14 inches high—in the prewhorl stage. Survival increased until the midgreen tassel period and gradually tapered off during the early and mid-silk stages. Larvae hatched during the late silk and roasting ear stages had sharply reduced survival. However, there are insufficient data for reaching a positive conclusion regarding the survival of larvae when the eggs hatch during these last two plant growth stages.

There are several inferences that can be made from these data. European corn borer larvae are unlikely to survive the growing season if hatched during the



FIGURE 17. Corn plant growth stages. (E) Late green tassel. (F) Early silk. (G) Midsilk. (H) Late silk.

prewhorl stage, when the plants are less than 14 inches high. Corn plants are most susceptible to borer infestation during the green tassel stages and before the silk becomes dry and brown. In Maine, corn planted late is more likely to escape serious infestation than early corn.

LARVAE COMMONLY CONFUSED WITH THE EUROPEAN CORN BORER

The corn earworm and the fall armyworm in their early larval stages are sometimes confused with the European corn borer. The color of the fall army-

worm is a dark gray when quite young and a little lighter shade of gray when older. This gray color helps to distinguish it from the pinkish or light brown color of the European corn borer. Stripes, a lighter gray, or sometimes a dull white, are located on each side of the body, and serve to set it off from the plain colors of the European corn borer. The underneath or ventral side of the body of the fall armyworm is quite light in color in contrast to the rest of the body. This is also true of the European corn borer, but the difference between the lower or ventral and the upper or dorsal sides of the bodies are more strik-

TABLE 13

Correlation of Corn Growth Stages with European Corn Borer Survival During the Years 1949, 1950, and 1951—Newport, Maine

Code	Stage of plant at hatching	Height of corn when eggs hatched (inches)	Hatching dates	Number hatched	Percentage larvae surviving	Number plants dissected
W-1	Prewhorl	3-14	June 23-July 20	2862	2.9	135
W-2	Early whorl	7-17	July 10-July 31	4463	5.5	159
W-3	Midwhorl	11-24	July 13-Aug. 10	8038	9.9	316
W-4	Late whorl	15-40	July 20-Aug. 14	2523	16.3	97
T-1	Early green tassel	21-46	July 22-Aug. 23	2867	26.2	108
T-2	Midgreen tassel	23-50	Aug. 1-Aug. 20	1386	28.3	60
T-3	Late green tassel	30-61	Aug. 6-Aug. 25	1673	27.0	75
S-1	Early silk	42-71	Aug. 9-Aug. 26	1374	26.6	67
S-2	Midsilk	56-79	Aug. 17-Aug. 28	1267	24.7	59
S-3	*Late silk	60-64	Aug. 27-Aug. 31	183	18.5	9
E-1	*Roasting ear	65-67	Aug. 28-Sept. 1	298	17.7	12
Totals				26,934		1097

* Occurred in 1950 only.

ing in the fall armyworm than in the corn borer. The fully grown fall armyworm attains a length of about $1\frac{1}{2}$ inches, while the body of the European corn borer seldom becomes more than 1 inch in length.

The fall armyworm is also confused with the corn earworm. However, the brownish or green color of the corn earworm is distinctly different from the gray shades of the fall armyworm. The size of the corn earworm when fully grown exceeds slightly that of the $1\frac{1}{2}$ inch length of the fully grown fall armyworm.

The corn earworm enters the corn ear through the silk channel, and in Maine seldom feeds except on the two or three inches of the top area of the ear. Our records show but a single corn earworm to each ear.

The corn earworm can be distinguished from the European corn borer because of its brownish or green color, because like the fall armyworm it comes late in the season, and because it always enters the tip of the corn ear.

Both the fall armyworm and the corn earworm are not native to Maine, but come in by flight from farther south. Infestation of both are periodic and

sometimes very mild. However, either or both may appear without much warning at any time, and since their advent is late in the season, it is difficult to control them. The fall armyworm may be controlled to some extent by late applications of DDT made for the European corn borer. Control of the corn earworm entails special applications of DDT, preferably with light oils or in emulsion form late in the season after the silks have been formed and pollenization has occurred. Three or more applications of DDT dust or sprays at three-day intervals have been reported as successful in controlling the corn earworm.

NATURAL ENEMIES OF THE CORN BORER

Parasites

Investigations of parasitic control of the European corn borer have been conducted for several years by the Maine Agricultural Experiment Station in co-operation with the U. S. Department of Agriculture.

In 1935 a large colony of parasitic flies *Lydella stabulans* Var. *Grisescens* R. was released in Wells, Maine. In

1949 and 1950 hymenopterous parasites *Chelonus annulipes* Wesm. and *Macrocentrus gifuensis* Ashm. were liberated in Androscoggin and Kennebec Counties. All of these imported parasites are known to attack the European corn borer; none are harmful to our beneficial insects. Field collections of European corn borers in Maine indicate that of the many exotic parasites released no significant number is now present, as only a single specimen of *Macrocentrus gifuensis* Ashm. was recovered at South Berwick in 1948.

Native parasites are present in the corn growing areas of Maine. The most common is *Aplomya caesar* Ald. of the order Diptera or flies, which lives in the bodies of larvae and eventually kills them. Other identified native parasites include the Diptera *Megaselia scalaris* Loew, *Chaetopsis aenea* Wied, and the minute hymenopterous egg parasite, *Trichogramma minitum* Riley.

Parasites, if they become established in large numbers, conceivably can control the European corn borer. At present they apparently are not established in sufficiently large numbers to be of economic significance in Maine. The experiences of other investigators, while encouraging, indicate that the effectiveness of parasitic control cannot be predicted with accuracy at this time; therefore, efforts at control by other methods known to be effective may be considered more practical under present conditions rather than depending on parasites for European corn borer control.

Predators

Predation by birds is destructive to the European corn borer larvae chiefly in the spring, when the borers are exposed in the corn fields in small pieces of corn stalk and again in the fall, in standing or partly plowed stalks. In some fields the degree of predation has been so extensive as to be economically important. The minute predaceous bug (*Orius insidiosus* Say) feeds upon the small borers when they are first hatched by sticking

their sharp beaks into the body and extracting the vital body juices thus killing the borers. Eggs and newly hatched larvae are also subject to predation by a number of ladybird or Coccinelid beetles and by the elaterid beetle *Cryptohypnus abbreviatus* Say.

BIVOLTINE STRAIN OF THE EUROPEAN CORN BORER

The bivoltine strain of the European corn borer has been abundant for many years in southern Maine. Recently it has been found in central Maine. Only once, however, has it been economically important. In August of 1949 a heavy second-generation infestation caused severe damage to a late crop at Hermon, Maine.

Probably the relatively early cold weather in central Maine prevents establishment of large numbers of the two-generation strain. At harvest time in late August and early September pupae frequently are found in the corn plants, but there is usually insufficient time for the larvae descended from these pupae to attain sufficient maturity to overwinter successfully.

The presence of the bivoltine strain in central Maine was established in 1949, 1950 and 1951 when pupae in growing corn plants were found. The earliest dates on which these pupae were observed are: 1949, July 11 at Auburn and July 15 at Hermon; 1950, August 2 at Newport; and 1951, August 21 at Newport. Fully grown larvae were removed from corn plants on August 14, 1951. They pupated on August 21. In 1949, between the dates of July 11 and August 12, second-generation pupae were found in 10 different towns in central Maine. Pupation by the two-generation strain of the European corn borer begins before single generation pupation has ended. Since the second generation of the bivoltine strain pupates inside growing corn or other plants, there is little danger of confusing them with the single generation which pupates in the dead host plants in which they overwinter.

The earliest pupae each year, often believed to be two generation, generally have been proven to be single strain pupae.

Pupae found in old plant material after the middle of July also are single-generation strain while those found in growing plants are of the two-generation strain.

Approximately 34 per cent of the moths were emerged at Wells in York County, Maine, on June 14, 1952, and moths were present in the fields on this date.

Pupation of second-brood borers has been observed beginning July 11 and it is probable that moths of this brood are on the wing from the latter part of July through the rest of the summer. Second brood moths have never been numerous enough in central Maine to cause severe infestation.

On August 1, 1949, a male and a female moth emerged from the two-generation pupae. Oviposition began on August 2. Over a period of five days the female laid 542 eggs, of which 321 hatched. The surviving larvae were overwintered in a cage.

On April 15, 1950, 45 of these larvae were still alive. Twenty-two developed into moths that emerged between the dates of June 10 and July 21. Fifty-four egg masses, consisting of 1320 eggs, were laid by the moths between July 11 and July 24, and 948 of these eggs (71.8 per cent) hatched between July 17 and August 2. An examination of the larvae on August 23 revealed that the largest were a little more than one-half grown. In late September the larvae were collected for overwintering.

Probably because of adverse overwintering conditions, by June 19, 1951, two

pupae and three larvae were all that had survived. From these one male and two female moths emerged. No fertile eggs were laid by these moths.

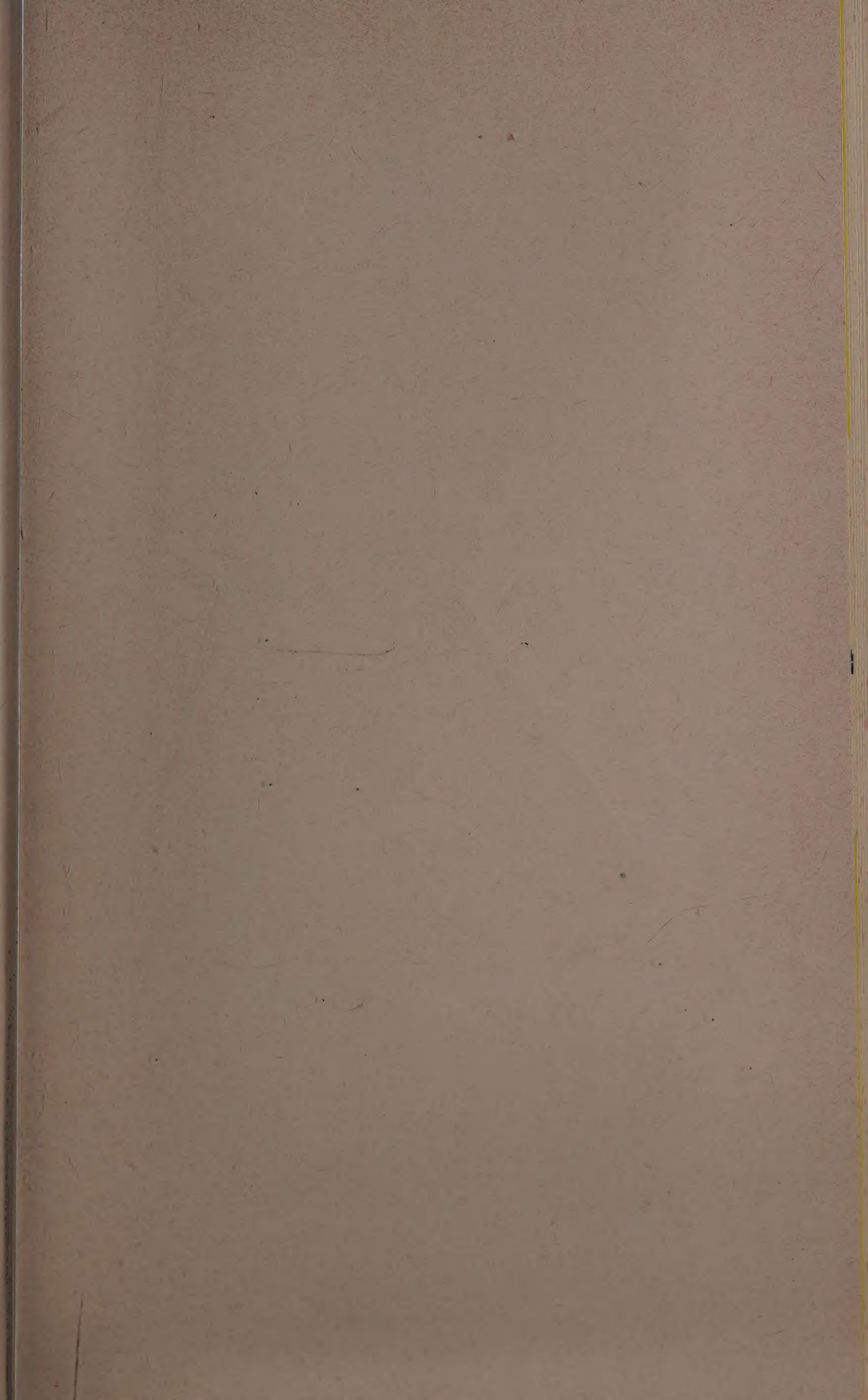
These data indicate that the bivoltine strain sometimes completes two full generations in one year and only one during the next. It is probable that many of the borers believed to be univoltine are really bivoltine, but due to the short season in central Maine complete only a single generation.

A study of the European corn borer at Wells in York County suggests that two distinct broods of the European corn borer is predominant there. Sometimes the damage to corn is greater from second brood than from the first brood borers. It is apparent that increase in the second or late summer brood is greater than is that of the overwintering generation.

The contradictory nature of the available data creates some doubt as to the presence in Maine of two distinct strains of the European corn borer. An alternate, defensible hypothesis is that there is but one strain present, but which is capable of completing either one or two life cycles each season. Factors determining the one or two-generation cycle in a given year may be differences in available plant food, weather variations, and individual physiological and anatomical characteristics. These conclusions are in agreement with Arbuthnot (1) who says, "The climate may limit the multiple generation strain to the production of one generation annually, whereas the single generation strain will produce but one generation annually in an environment permitting more than one generation of the multiple generation strain."

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